



Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

DEMOGRAPHICS AND POST-STOCKING SURVIVAL OF REPATRIATED RAZORBACK SUCKER IN LAKE MOHAVE



August 2007

Lower Colorado River Multi-Species Conservation Program

Steering Committee Members

Federal Participant Group

Bureau of Reclamation
Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Indian Affairs
Western Area Power Administration

Arizona Participant Group

Arizona Department of Water Resources
Arizona Electric Power Cooperative, Inc.
Arizona Game and Fish Department
Arizona Power Authority
Central Arizona Water Conservation District
Cibola Valley Irrigation and Drainage District
City of Bullhead City
City of Lake Havasu City
City of Mesa
City of Somerton
City of Yuma
Electrical District No. 3, Pinal County, Arizona
Golden Shores Water Conservation District
Mohave County Water Authority
Mohave Valley Irrigation and Drainage District
Mohave Water Conservation District
North Gila Valley Irrigation and Drainage District
Town of Fredonia
Town of Thatcher
Town of Wickenburg
Salt River Project Agricultural Improvement and Power District
Unit "B" Irrigation and Drainage District
Wellton-Mohawk Irrigation and Drainage District
Yuma County Water Users' Association
Yuma Irrigation District
Yuma Mesa Irrigation and Drainage District

Other Interested Parties Participant Group

QuadState County Government Coalition
Desert Wildlife Unlimited

California Participant Group

California Department of Fish and Game
City of Needles
Coachella Valley Water District
Colorado River Board of California
Bard Water District
Imperial Irrigation District
Los Angeles Department of Water and Power
Palo Verde Irrigation District
San Diego County Water Authority
Southern California Edison Company
Southern California Public Power Authority
The Metropolitan Water District of Southern California

Nevada Participant Group

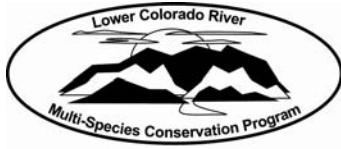
Colorado River Commission of Nevada
Nevada Department of Wildlife
Southern Nevada Water Authority
Colorado River Commission Power Users
Basic Water Company

Native American Participant Group

Hualapai Tribe
Colorado River Indian Tribes
The Cocopah Indian Tribe

Conservation Participant Group

Ducks Unlimited
Lower Colorado River RC&D Area, Inc.



Lower Colorado River Multi-Species Conservation Program

DEMOGRAPHICS AND POST-STOCKING SURVIVAL OF REPATRIATED RAZORBACK SUCKER IN LAKE MOHAVE

Lower Colorado River
Multi-Species Conservation Program Office
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
<http://www.usbr.gov/lc/lcrmscp>

August 2007

**DEMOGRAPHICS AND POST-STOCKING SURVIVAL OF
REPATRIATED RAZORBACK SUCKER IN LAKE MOHAVE**

Final 2006 Annual Report

Brian R. Kesner, Abraham P. Karam,
Carol A. Pacey, and Paul C. Marsh

Native Fish Lab
School of Life Sciences
Arizona State University
Tempe, Arizona 85287-4501

In behalf of Agreement No. 06-FC-300003

between

Arizona State University

and

U.S. Bureau of Reclamation

Boulder City, Nevada 89006

April 30, 2007

SUMMARY

Four general areas of inquiry were pursued on Lake Mohave during the period covered by this report: (1) razorback sucker post-stocking dispersal and fate (including large-mesh gill netting, underwater observation and videography, and sonic telemetry), (2) routine monitoring, (3) creel census, and (4) ecological modeling.

Approximately 500 sub-adult razorback suckers were stocked at Fortune Cove on each of two consecutive days. The batch released on the second day included 20 sonic tagged fish. Large-mesh gill nets set for three days during and after the two-day release event captured no fish of any species. Direct underwater observations of the releases indicated that most stocked fish dispersed shoreward and fewer than 30% of fish moved toward open water.

Tagged fish were tracked manually and by remote sensors for four months from 27 September 2006 to 25 January 2007. There were 199 individual contacts. Forty-nine contacts were by remote sensors and 41 (84%) of these were during night time hours. Twenty-four hours following release, 61% of tagged fish were at or near (< 0.5 km) the stocking site, while later in the study about half the fish displayed a trend for upstream dispersal. At least eleven fish had died and ten of their tags were recovered by mid-January 2007 (55% mortality), all presumably killed by striped bass.

ASU handled 32 razorback suckers (33 captures, one short-term recapture) in 2006, with 36% of the captures during March roundup. There were 27 PIT tagged repatriates, three PIT tagged fish with unknown capture histories, one wild PIT- tagged fish, and one untagged fish. Based on monitoring data from 2005 and 2006, we estimate the current wild razorback sucker population Lake Mohave is 507 fish (263-1,067 95% confidence interval). The repatriated razorback sucker population is estimated to number 4,221 (954-35,071 95% confidence interval) with a 4% estimated survival of all repatriates released as of March 1, 2005. The current total population estimate for razorback sucker in Lake Mohave is 4,728.

Few striped bass longer than 80 cm have been processed by the NVDOW creel census, and none has contained a PIT. Additional observations are needed.

Wild razorback suckers are significantly more likely to be recaptured in the zone of capture than in any other zone. This is true regardless of time at large or time of year. Similarly, repatriated fish were more likely to be captured in the zone of release than in any other zone.

INTRODUCTION

Lake Mohave is home to the largest remaining population of wild razorback suckers. Historically, this population contained more than one hundred thousand fish, but numbers have dwindled dramatically in recent years and it currently is made up of fewer than 500 individuals (Marsh et al. 2003, Turner et al. 2007, ASU Native Fish Lab unpublished data). A repatriation program for restoring razorback sucker in Lake Mohave was begun in the early 1990s (Mueller 1995). The program utilizes wild-produced larvae that are reared in protective captivity and then repatriated to the lake after growing to a nominal size of 30 cm or more. There have been a number of adjustments to the program that incorporate new information and attempt to increase survival of stocked fish, but results thus far have not met expectations (Marsh et al. 2005).

Razorback sucker like many other native fishes of the region is on a trajectory that soon will lead to its extirpation in the wild in the lower Colorado River (Marsh 1996, Mueller & Marsh 2002). Conservation plans for big-river fishes in the lower Colorado River (Minckley et al. 2003, USFWS 2005) incorporate a population component that will occupy the main stream, but it may be impractical or impossible to accommodate that plan. If main channel populations cannot be developed and maintained, conservation of razorback sucker in the lower river may depend entirely on populations in off-channel habitats that are free of non-native fishes. It is an objective of this research to provide information needed to determine how each of these strategies should contribute to maintenance of razorback sucker in Lake Mohave and throughout the lower Colorado River. Moreover, our results will provide critical demographic information and management recommendations to help ensure the long-term persistence of a genetically viable stock of adult razorback sucker in Lake Mohave.

This report summarizes our findings for the first year of the project, 2006. An initial round of sonic telemetry coupled with direct observation of fish behavior upon release

and large-mesh gill netting has provided insights into short-term dispersal, behavior and mortality of released fishes. Continuation of standard monitoring has provided updated population and survival estimates for wild and repatriate populations, creel census data on large striped bass abundance and impact on razorback sucker stockings are currently being provided through collaboration with Nevada Department of Wildlife (NVDOW), and an ecological model describing the processes of survival and movement of Lake Mohave razorback suckers is in the early stages of development.

METHODS

Post-stocking Dispersal and Fate

Activities during 26-27 September 2006 surrounded a two-day, experimental stocking of sub-adult razorback suckers into Lake Mohave, as detailed below. First, large-mesh gill nets were deployed. Next, a dive team entered the water and about 500 fish from U.S. Fish and Wildlife Service Willow Beach National Fish Hatchery, Willow Beach, Arizona (Willow Beach NFH) were released. The same protocol was repeated the next day when about 480 fish plus 20 fish implanted with sonic tags were released at the same location. Nets were inspected periodically throughout the experimental period, and telemetry tracking commenced when the tagged fish were released.

Large-mesh Gill Netting

Prior to release of razorback suckers into Fortune Cove, ten monofilament gill nets (45.7 x 3.1 m, 20.3 cm stretch mesh) were set in and around the stocking site (Fig. 1), and fished continuously for 72 hours. The large net mesh size was chosen to target large-bodied piscivorous fish (specifically striped bass) but allow smaller sub-adult razorback suckers and other non-target fish to pass through the net without becoming entangled. Two nets were deployed near Oro Cove (UTM 11S 0707755 E, 3955660 N), four inside Fortune Cove (UTM 11S 0707780 E, 3955974 N), and four near the entrance to Elizabeth J. Cove (UTM 11S 0707950 E, 3956560N). Nets were set from shore to a depth of 5-8 m. If non-native predators were caught, specimens were sacrificed, their gut contents excised, and examined for evidence of predation on stocked fish.

SCUBA Observation and Videography

During both release dates at Fortune Cove, up to five members of the USBR Lower Colorado Region Dive Team were positioned underwater near the release boat with writing slates and digital video recording equipment to document the dispersal behavior and potential predation of razorback suckers as they were released. Divers took notes on fish schooling behavior and direction of travel (cove or lake, surface or bottom).

Sonic Telemetry

Twenty razorback suckers (average TL 38.1 cm, range 35.5 – 45.5) were collected from a hatchery stock of sub-adult razorback suckers on 25 September 2006 at Willow Beach NFH. All individuals had previously received a 400 kHz PIT tag for positive identification. Fish were transferred into an indoor raceway and allowed to acclimate for 30 minutes prior to surgery. Each fish was scanned for a PIT tag, anesthetized with tricaine methanesulfonate (MS222; 125 mg L⁻¹), and surgically implanted with a sonic transmitter (Sonotronics model IBT-96-6-I) (adapted from Mueller et al. 2000). Following surgery, a 0.20 ml dose of the broad spectrum antibiotic Baytril® (Enrofloxacin) was injected into dorsolateral musculature of each fish as a preventative measure for post-surgery infection (Martinsen & Horsberg 1995). All fish were placed in a recovery raceway with continuous fresh water flow-through and monitored for two days to evaluate health and tag retention¹.

On 27 September 2006, all 20 telemetry fish were placed into an 1,893-L, aerated tank along with ~480 additional sub-adult razorbacks, transported by boat downriver from Willow Beach NFH, and released into Fortune Cove near river mile (RM)² 41 on the NV side of the reservoir (Fig. 1). These fish were released as a part of an experimental, two-day stocking event in which a total of 1,034 razorback suckers were repatriated to Lake Mohave (~500 fish were released each on 26 and 27 September) at Fortune Cove (see below). All fish contained 400 KHz PIT tags.

¹ To more closely address the issue of fish survival following sonic tag surgery, we designed and implemented a “dummy tag” experiment that allowed for detailed monitoring of fish health and tag retention over a 3-month period.

² River miles (RM) are measured upriver (north) from Davis Dam.

Submersible Ultrasonic Receivers (SURs; Sonotronics model SUR-1) were used to detect the dispersal of sonic tagged fish after stocking. SURs were deployed in the main channel upstream (Chalk Cliffs, RM 43) and downstream (Gold Bug Cove, RM 35 and Sheep Trail Light, RM 31) of the stocking zone at Fortune Cove. When a fish was contacted by an SUR, the respective unit was moved in order to broaden the search area for all telemetry fish.

During the first 30 days post-release, intensive listening surveys were conducted by boat in coves, inundated washes, and the main river channel between the upper and lower-most deployed SURs. Transmitted signals were detected using a hand-held, directional hydrophone and a USR-96 Ultrasonic receiver (Sonotronics, Inc.). After the initial month following stocking, weekly surveys were conducted by boat using a pre-established survey grid composed of 148 way-points or "listening stations" programmed into a Global Positioning System (GPS) navigational system. Survey efforts were concentrated between lower and uppermost deployed SURs. Surveys terminated if no fish dispersed beyond the downstream-most SUR station. Periodic surveys of the entire lake (all 148 listening stations) were made to ensure no fish had dispersed undetected beyond the lowest deployed SUR.

Upon detection, each tagged fish was triangulated to its exact location. If feasible, return trips were made within 1-3 days to relocate previously contacted fish. When re-contacts were made in the same location, a SCUBA diver was deployed with an Underwater Diver Receiver (Sonotronics, Inc.) to locate and attempt to recover the sonic tag. The diver noted presence/absence of fish remains in the vicinity of a located tag.

Routine Monitoring

ASU personnel routinely occupy a field camp on Lake Mohave at Carp Cove, Arizona, near RM 20. Trammel netting and other program-related activities such as razorback sucker larval collections are implemented from that site. From March 13-17, 2006, six trammel nets (91.4 x 1.8 m, 3.8-cm stretch mesh) were fished continuously along the Arizona shoreline from Pot Cove upstream to Carp Cove. Five trammel nets (same dimensions and mesh) were deployed in the same general area from May 15-19, 2006 and from November 11-15, 2006.

Native fishes encountered were processed (measured, sexed, scanned for a PIT tag and tagged if none was present, and examined for general health and condition) and released. A fin clip was taken from a sub-sample of razorback suckers, placed in 1 ml of 95% ethanol in a snap-cap tube, and returned to the laboratory for genetic analysis (reported elsewhere). All relevant data are entered into the comprehensive lower river PIT tag database maintained by ASU.

Creel Census Data

Creel census data are collected once a week by a Nevada Department of Wildlife biologist stationed at Cottonwood Landing, Nevada. Currently, any striped bass greater than 80 cm in total length in the creel census will be scanned for PIT tags. A striped bass that is 80 cm long has a gape width that will allow it to consume razorback sucker prey that is 35 cm long (Kesner et al. 2005), which for many years was the minimum length at stocking for fish being repatriated to Lake Mohave (the current minimum stocking length is 50 cm, a size unlikely to be eaten by any striped bass in the lake). If a PIT tag is found inside a striped bass, the stomach will be removed and sent to the Native Fish Lab at ASU.

Ecological modeling

Ecological modeling is still in its early stages of development. Lake Mohave was divided into 'zones' at two spatial scales in order to determine the level of site fidelity exhibited by razorback suckers (Figs. 2 & 3). Zones were based on the physical characteristics of the lake as well as previously established divisions utilized by the Lake Mohave Native Fish Work Group (NFWG) for sampling effort distribution. Zones were developed as polygons within ArcGIS (ArcMap™ 9.1, ESRI), and overlapped both shorelines to include all GPS net and fish locations from sampling trips and releases. Capture-recapture and release-recapture data were summarized into contingency tables by zone so that frequency analysis could be used to determine if release or capture site significantly affected capture or recapture site (site fidelity) for wild and repatriated razorback suckers. To date, generalized zones have been analyzed. The Lower Lake Zone was excluded from analysis due to a lack of captures or recaptures, which was a result of little sample effort applied in that area.

RESULTS

Post-stocking Dispersal and Fate

Combined results of this area of investigation were a mixed bag, but overall a considerable volume of new information and experiential benefits were gained. Large-mesh gill netting was fruitless, but underwater observations and sonic telemetry produced valuable insights and direction for continued studies.

Large-mesh Gill Netting

Gill nets were deployed continuously prior to, during, and after the razorback sucker release. Nets were checked daily at sunrise, mid-day, and again after dark. Total effort was 720 net-hrs and catch was zero fish.

SCUBA Observation and Videography

SCUBA observations from both dates indicated the vast majority of stocked razorback suckers swam at a steep angle toward the bottom, and to the back of Fortune Cove immediately following their release. Divers estimated between 20-27% of released fish swam outward, towards the open waters of the reservoir, while the majority of remaining razorbacks dispersed towards the back of the Fortune Cove. Most of these fish took cover in the extensive weed beds located at the bottom of the cove. Following the stocking events on both dates, few fish were observed throughout the cove leading divers to theorize fish remained hidden in the extensive cover of submerged vegetation found at the bottom of Fortune Cove.

Sonic Telemetry

Between 27 September 2006 and 25 January 2007, all 20 tagged fish were contacted, for a total of 199 individual fish contacts. Throughout this period, a considerable number of tagged fish were located in the vicinity of Fortune Cove (RM 41, Fig. 4). Twenty-four hours following their release, 61% of all tagged fish were contacted at or near (< 0.5 km) Fortune Cove. Over time, approximately 50% of all tagged fish were routinely contacted near the stocking site, while remaining fish displayed a trend for upstream dispersal.

The re-deployment of an SUR on 25 October 2006 upstream to Fortune Cove greatly improved our ability to detect fish returning to or residing near the stocking site (Fig. 5). Of the 199 total contacts made to date, 49 were made with SURs, of which, 41 (84%) were made during night time hours.

By 24 October 2006, tagged fish had dispersed between Painted Canyon Lights (RM 24) and the USGS gauging station (RM 54) upstream of Willow Beach. Despite intensive search efforts, no fish were located between RM 54 and Hoover Dam (RM 64). To date, only one fish dispersed downstream of Painted Canyon Lights into the open reservoir basin near Cottonwood Cove (RM 22), then unexpectedly returned to the upper portion of the lake. On two separate trips, the entire lake was surveyed (all 148 listening stations) confirming that no fish had moved past the lowest SUR deployed at Painted Canyon Lights.

As of 25 January 2007, 11 of 20 (55%) tagged fish stopped moving. Of those eleven individuals, ten sonic tags were recovered from the bottom of the lake by a SCUBA diver. The location of one tag (Fish 8) was established, but due to a flash flood and its proximity near a wash, the diver was not able to recover the tag, presumably because it was buried under a layer of fine sediment (Table 1). It is important to note that no fish remains were found near any recovered tag. All 11 deceased fish had a history of actively swimming and were frequently contacted by manual and SUR tracking prior to becoming stationary and the subsequent recovery of each tag (Fig. 6 and Table 1).

Routine Monitoring

ASU handled 32 razorback suckers (33 captures, one short-term recapture) in 2006 with 36% of the captures during March roundup (Table 2). Of these fish, 27 were PIT tagged repatriates, three were PIT tagged fish with unknown capture histories (i.e., no capture or release data in the NFWG database), one was a wild PIT- tagged fish, and one was an untagged fish. The one untagged fish was suspected to be a repatriate due to size and overall condition. The one wild fish was a male originally captured eight years earlier in 1998, near Willow Cove and Half-way Wash, Nevada in the Basin Zone, approximately three river miles south and across the lake from the ASU monitoring area. For purposes of this report, only the 27 repatriated fish with paired release-capture data

will be discussed further; data were omitted from six fish with unknown or wild history, captured during the same trip, or without a tag.

Twenty fish were captured in 2006 for the first time since their release into the lake while seven fish were captured for the second time (Table 3); no fish had more than two captures, even fish at large for more than 13 years. Most of the fish were tagged in the current decade (N = 20) while seven fish were tagged in the 1990s, with the oldest tag from 1992. Fourteen fish were at large less than a year while 13 were at large for four years or more with five of these fish at large for more than 10 years. Nine fish with year class information ranged from approximately two to four years old at stocking with most at large less than one year.

Nine fish were less than 35.0 cm TL at release, 18 fish were greater than 35.0 cm TL at release, and all fish were greater than 34.0 cm TL upon capture (Table 4). Of the fish at large for less than one year, growth ranged from -1.4 to 1.1 cm TL/month, while fish at large for four years or more, growth ranged from 0.1 to 0.7 cm TL/month. Negative values were likely due to measurement errors at release or capture.

Off-site rearing facilities contributed 55% of the total fish captured with the majority reared at Willow Beach NFH (Table 5). Yuma Cove contributed the most fish from lakeside backwaters, contributing 22% of the total fish captured, with five fish released into the lake from 1992 to 1995, and one released in 2005. Fish released at Nevada's Nelson's Landing and Placer Cove traveled the furthest, approximately 32 km downstream to ASUs monitoring area. Others traveled 5 to 21 km from their release sites on both sides of the reservoir, while one fish traveled less than 1.6 km from Pot Cove, Arizona. ASU monitors only in the Basin Zone, and we captured fish released from all four zones in March, but only two zones in May and November (Fig. 7). Fish released from the Arizona Bay Zone contributed 48% of the total fish captured during 2006, while 41% of the total fish captured in the Basin Zone were released in the Basin Zone. More than half of the fish captured in the Basin Zone (54%) were released in 2006.

Based on monitoring data from 2005 and 2006, we estimate that the current wild razorback sucker population Lake Mohave is 507 fish (263-1,067 95% confidence interval). It is suspected that this estimate is inflated, because fish without tags have

traditionally been labeled as 'wild' fish, but in recent times these untagged fish are clearly young, healthy and likely repatriated fish. We estimate that the repatriated razorback sucker population is 4,221 (954-35,071 95% confidence interval) with a 4% estimated survival of all repatriates released as of March 1, 2005. We attribute the large span in the confidence interval to the low number of second captures. The current population estimate for razorback sucker in Lake Mohave is 4,728.

Creel Census Data

Three striped bass over 80 cm have been processed by the creel census, and to date, none have contained PIT tags.

Ecological Modeling

Wild razorback suckers are significantly more likely to be recaptured in the zone of capture than in any other zone (χ^2 homogeneity test, $p < 0.001$, $df = 7$). This is true regardless of time at large (Fig. 8) or time of year (Fig. 9). Few captures have been made in the River and Lower Lake zones; however, effort is low in these two zones.

Repatriate razorback sucker analysis results were similar. Repatriated fish were more likely to be captured in the zone of release than in any other zone (>720 days at large, χ^2 homogeneity test, $p < 0.001$, $df = 7$).

DISCUSSION

Post-stocking Dispersal and Fate

Large-mesh gill netting

The lack of striped bass captures in large-mesh gill nets suggests trivial predation pressure on razorback repatriates in the vicinity of Fortune Cove immediately after and during the three day post-stocking period. However, this could be a result of seasonal factors or serendipity, for example, if larger striped bass were dispersed to other parts of the reservoir during the stocking period. Catch data and creel results unequivocally demonstrate the presence of large striped bass, to longer than a meter, in Lake Mohave,

and these fish likely prey on razorback suckers. Additional directed and opportunistic sampling may be needed to further address this issue.

SCUBA Observation and Videography

Visual surveys conducted by SCUBA divers indicated a vast majority of stocked razorbacks initially swam to the back of Fortune Cove and took cover in the extensive submergent weed beds following their release. Subsequent analysis of underwater video footage recorded by divers confirmed this dispersal trend toward submergent cover and did not indicate the presence of any large-bodied piscivorous fish loitering in the stocking area. If a majority of stocked fish immediately found cover and remained out of view of potential predators, as suggested by the dive team, and no large striped bass were cued in by the two stocking events, it is reasonable to conclude predation of repatriated fish in the close vicinity of the stocking site was negligible. We do not know if this is a typical or aberrant result.

Sonic Telemetry

Upon close inspection of the nearly continuous telemetry observations taken between upper and lower SURs during the first week following stocking, predation arguably became an important factor to fish survival after repatriates dispersed beyond Fortune Cove into the open, deeper waters of Lake Mohave. While telemetry observations from the first week confirmed 1) a considerable number of tagged fish remained in or returned to Fortune Cove following their release, and 2) a majority of tagged fish remained active (alive) post-stocking, data also indicated that tagged fish ventured well beyond the stocking area into deeper water (15-20 m) of the reservoir, where visual observations and gill net sets were not feasible. One of twenty tagged fish (5%) was likely consumed by a predatory fish 1-2 days following its release (Table 1, Fish 4). Based on the swimming history of Fish 4, it is highly probable that it was eaten by a piscivorous fish following its departure from Fortune Cove. Fish 4 dispersed rapidly upstream after initially being contacted in the main channel outside the stocking site, then three days later, the tag abruptly stopped moving and was subsequently recovered by a SCUBA diver ~9 km upriver. No visible fish remains observed with the tag only three days after it stopped moving.

Survival of telemetry tagged fish decrease initially, was stable at 60% between the fifth and 11th weeks following stocking, and then decreased again (Fig. 10). By week 18, roughly 4 months following the razorback stockings in Fortune Cove, survival (45%) had dropped close to our initial one year survival estimate based on mark-recapture data (~41%). It is highly likely that the chances of a repatriated razorback encountering a large predatory fish while swimming in the open, deeper waters of Lake Mohave were greatly increased after leaving the extensive cover found at the release site. It is important to consider that these observations account for a trivial amount of time (4 months) in the lifespan of fish which can exceed 40 years (McCarthy & Minckley 1987).

A “dummy tag” experiment is currently underway at the Willow Beach NFH to address concerns of surgically-induced mortality and tag expulsion or loss. Surgical procedures for the dummy tags closely followed that of the surgeries for sonic tags. The dummy tagged fish are being monitored in a raceway at Willow Beach NFH to monitor their survival and to identify tag loss if it occurs. Final results are pending, but preliminary data suggest post-surgical mortality and tag loss are not an issue for this research.

Routine Monitoring

Population estimates for wild razorback sucker in Lake Mohave have hovered near 500 fish for several years (Marsh et al. 2003 & 2005, Turner et al. 2007), but confidence intervals are wide and actual number of fish may be substantially fewer than estimated. Natural recruitment to native fish populations in Lake Mohave is undetected, and whatever old, wild fish remain today are certain to perish in the coming years.

Repatriates in Lake Mohave outnumber wild adults by almost an order of magnitude, and this population was established and has been supported by stockings of relatively small fish, though stocking size minimum has periodically increased (Marsh et al. 2005). With a realization that large striped bass may be a prime source of post-stocking razorback sucker mortality, a new protocol has been adopted under which only fish longer than 50 cm will be stocked. It cannot be predicted how long it will be before any increase in survival can be demonstrated as a result of the new size standard, but it is hoped that a favorable result will be evident within a the first few years of implementation.

Creel Census Data

NVDOW collects weekly creel data at Cottonwood Cove, Nevada, but Arizona Game and Fish Department no longer conducts creel census at its fisherman's station at Willow Beach. Typically, Willow Beach razorback suckers have been stocked closer to the hatchery than to Cottonwood Cove, which is nearly 50 km downstream. As a result, large striped bass captured near razorback sucker stocking sites are likely to be brought into Willow Beach, not Cottonwood Cove. Therefore the lack of data from Willow Beach has a significant impact on our ability to detect predation. NVDOW will continue to provide us with data from Cottonwood Cove, and we will continue to seek cooperators so that we may acquire similar data from Willow Beach.

Ecological Modeling

Site fidelity has the potential to bias population estimates if effort is not equally distributed among areas of razorback sucker concentrations. The lack of recent effort in the lower-most lake prohibits measuring the level of site fidelity for the general zones. Further analysis using the more specific zones will be conducted, but we also recommend future sample efforts to include lower lake, and even if the catch from such efforts is low or nil the results will contribute toward a more useful model.

Other facets of this general area of inquiry are being developed or have been implemented for too short a time, and results are not available. For example, structure (distribution of age/size or life stage classes, sex ratio) and dynamics (growth, mortality, reproduction) of repatriate populations are being studied, and this project will acquire appropriate data to integrate ecological modeling of these metrics into program assessment and to support management recommendations.

It also has become apparent that currently employed models fail to account for all mortality factors affecting repatriated razorback suckers, or that there is significant sampling bias in March samples (see above). When fully implemented we expect the ecological modeling portion of this project will allow the development of specific mark-recapture models for repatriated razorback suckers in Lake Mohave. Our team plans to develop a suite of mathematical models to formally represent different hypotheses of survival and sampling bias.

Finally, by the conclusion of this study, we anticipate that measures of sampling bias, annual survivorship, and site fidelity, increased resolution of size based mortality, and predictions on stocking requirements to meet the Lake Mohave NFWG goal of an established population of 50,000 repatriates will be the products of the modeling project.

ACKNOWLEDGEMENTS

Collections were under permit authorization of U.S. Fish and Wildlife Service, National Park Service (Lake Mead National Recreation Area) and the states of Arizona and Nevada. Animal use was under IACUC protocol no. 05-767R to the principal investigator. Individuals who contributed their time and energy to this project in various capacities include T. Burke, M. Burrell, J. Campbell, B. Contreras, J. Lantow, J. Nelson, J. Schooley, M. Schwemm, J. Scott, T. Wolters, and the Reclamation dive team, J. Burke, G. Clune, R. Tang, and W. White under the leadership of Caireen Uleplic. All, plus others not named, are thanked for their time and effort in behalf of the fish.

LITERATURE CITED

- Kesner, B. R., P. C. Marsh & C. A. Pacey. 2005. Striped bass predation reducing survival of razorback sucker in Lake Mohave. Proceedings of the Desert Fishes Council.
- Marsh, P.C. 1996. Threatened fishes of the world: *Xyrauchen texanus* (Abbott, 1860) (Catostomidae). Environmental Biology of Fishes 45: 258.
- Marsh, P.C., Pacey, C.A. & B.R. Kesner. 2003. Decline of the razorback sucker in Lake Mohave, Colorado River, Arizona and Nevada. Transactions of the American Fisheries Society 132:1251-1256.
- Marsh, P.C., Kesner, B.R. & C.A. Pacey. 2005. Repatriation as a management strategy to conserve a critically imperiled fish species. North American Journal of Fisheries Management 25:547-556.
- Martisen, B. & T.E. Horsberg. 1995. Comparative single-dose pharmacokinetics of four quinolones, oxolinic acid, flumequine, sarafloxacin, and enrofloxacin in Atlantic salmon (*Salmo salar*) held in seawater at 10°C. Antimicrobial Agents and Chemotherapy 39(5): 1059-1064.
- McCarthy, M. S. & W. L. Minckley. 1987. Age estimation for razorback sucker (Pisces: Catostomidae) from Lake Mohave, Arizona and Nevada. Journal of the Arizona-Nevada Academy of Sciences 21:87-97.

Mueller, G. 1995. A program for maintaining the razorback sucker in Lake Mohave. Pages 127-135 in H.R. Schramm, Jr. & R. G. Piper, editors. Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society Symposium 15, Bethesda, MD.

Mueller, G.A. & Marsh, P.C. 2002. Lost, a desert river and its native fishes: A historical perspective of the Lower Colorado River, Information and Technology Report USGS/BRD/ITF—2002-0010: U.S. Government Printing Office, Denver, CO. 69p.

Mueller, G.A., Marsh, P.C., Knowles, G. & T. Wolters. 2000. Distribution, movements, and habitat use of razorback sucker (*Xyrauchen texanus*) in a lower Colorado River reservoir, Arizona-Nevada. *Western North American Naturalist* 60(2): 180-187.

Turner, T. F., T. E. Dowling, P. C. Marsh, B. R. Kesner & A. T. Kelsen. 2007. Effective size, census size, and genetic monitoring of the endangered razorback sucker, *Xyrauchen texanus*. *Conservation Genetics* 8: 417-425.

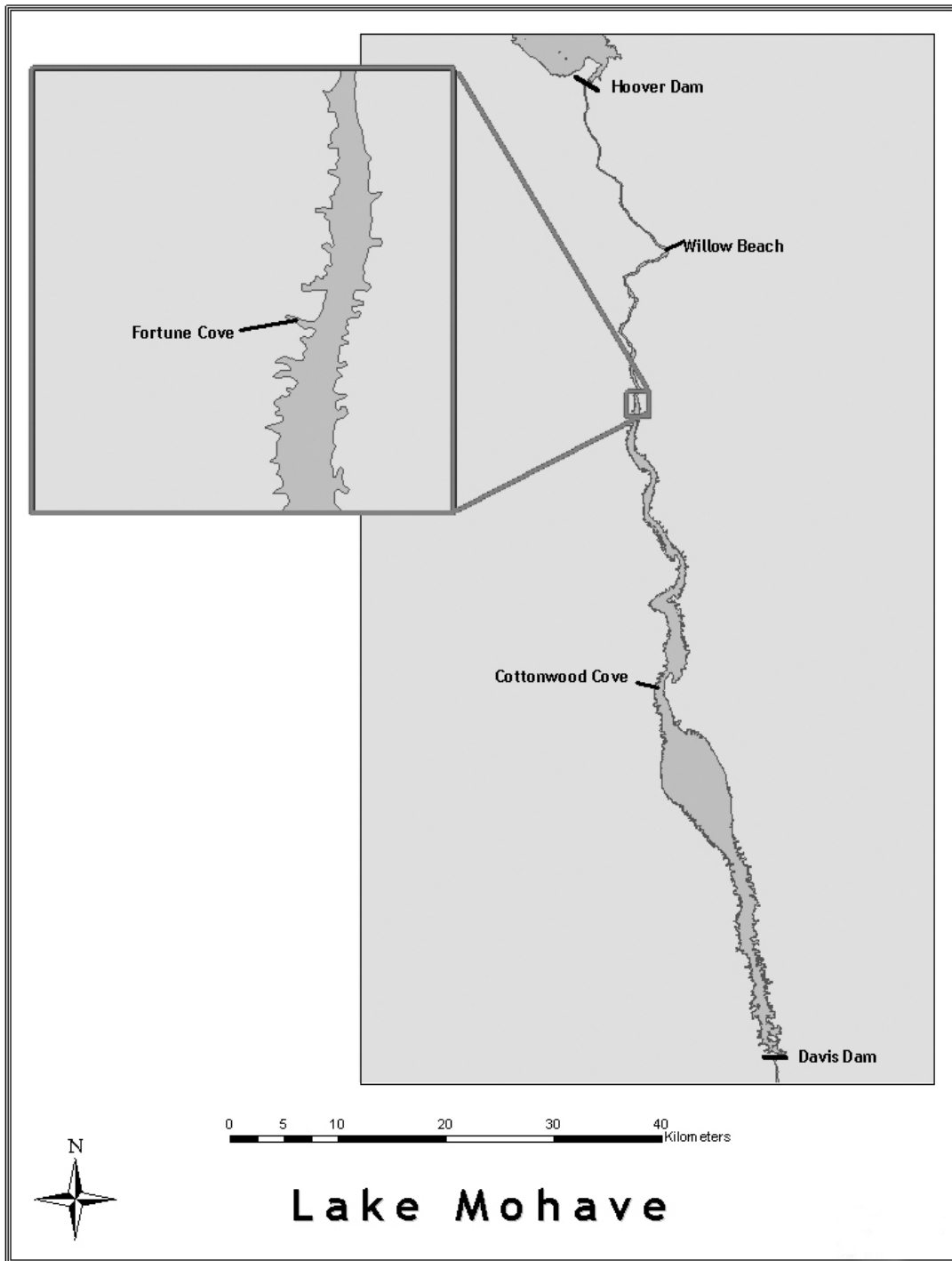


Figure 1. Map of Lake Mohave, Arizona and Nevada, and Fortune Cove where a total of 1,034 razorback suckers were stocked on 26 and 27 September 2006.

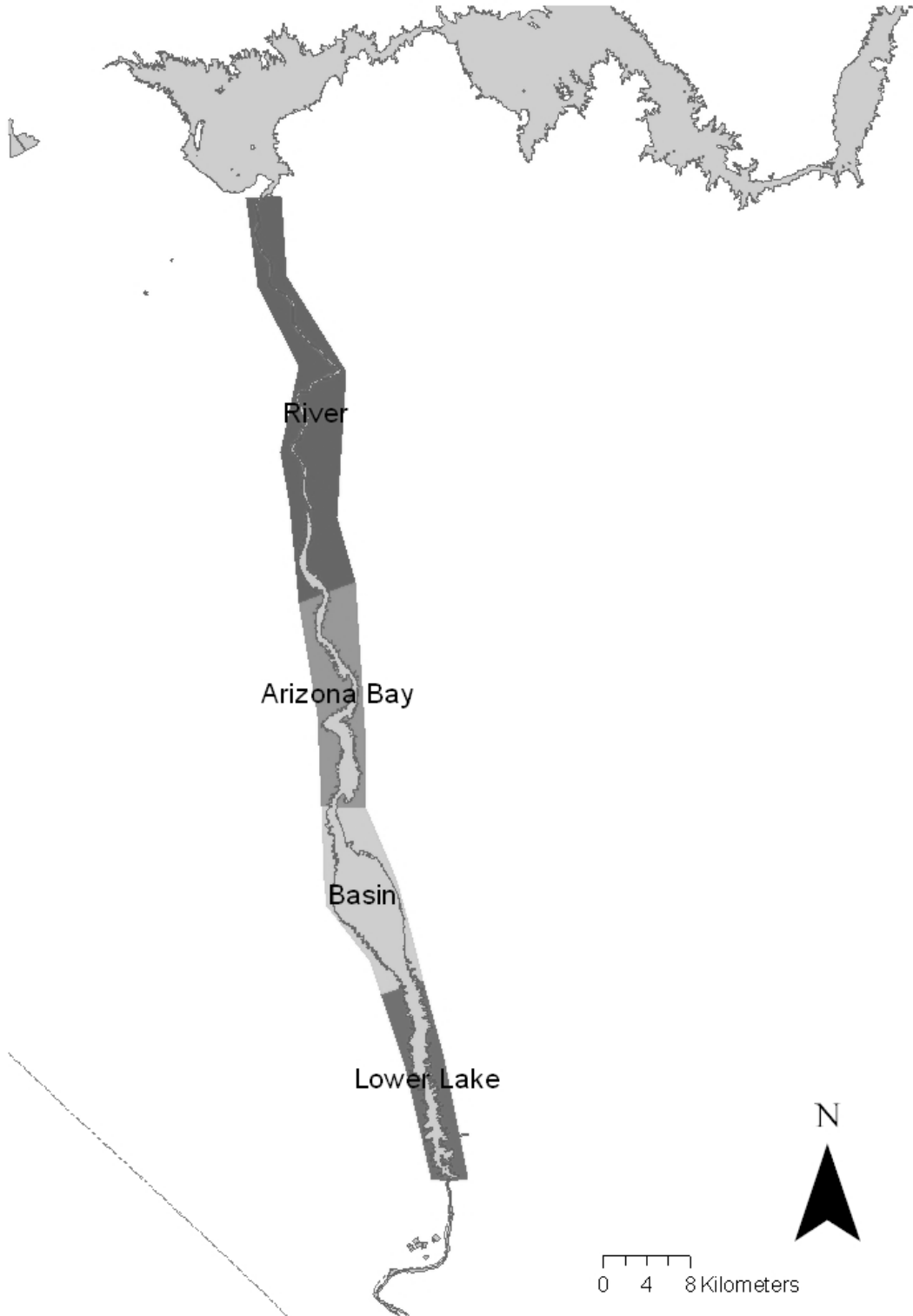


Figure 2. General zone names and boundaries used to analyze razorback sucker release, catch and effort data for Lake Mohave, Arizona and Nevada.

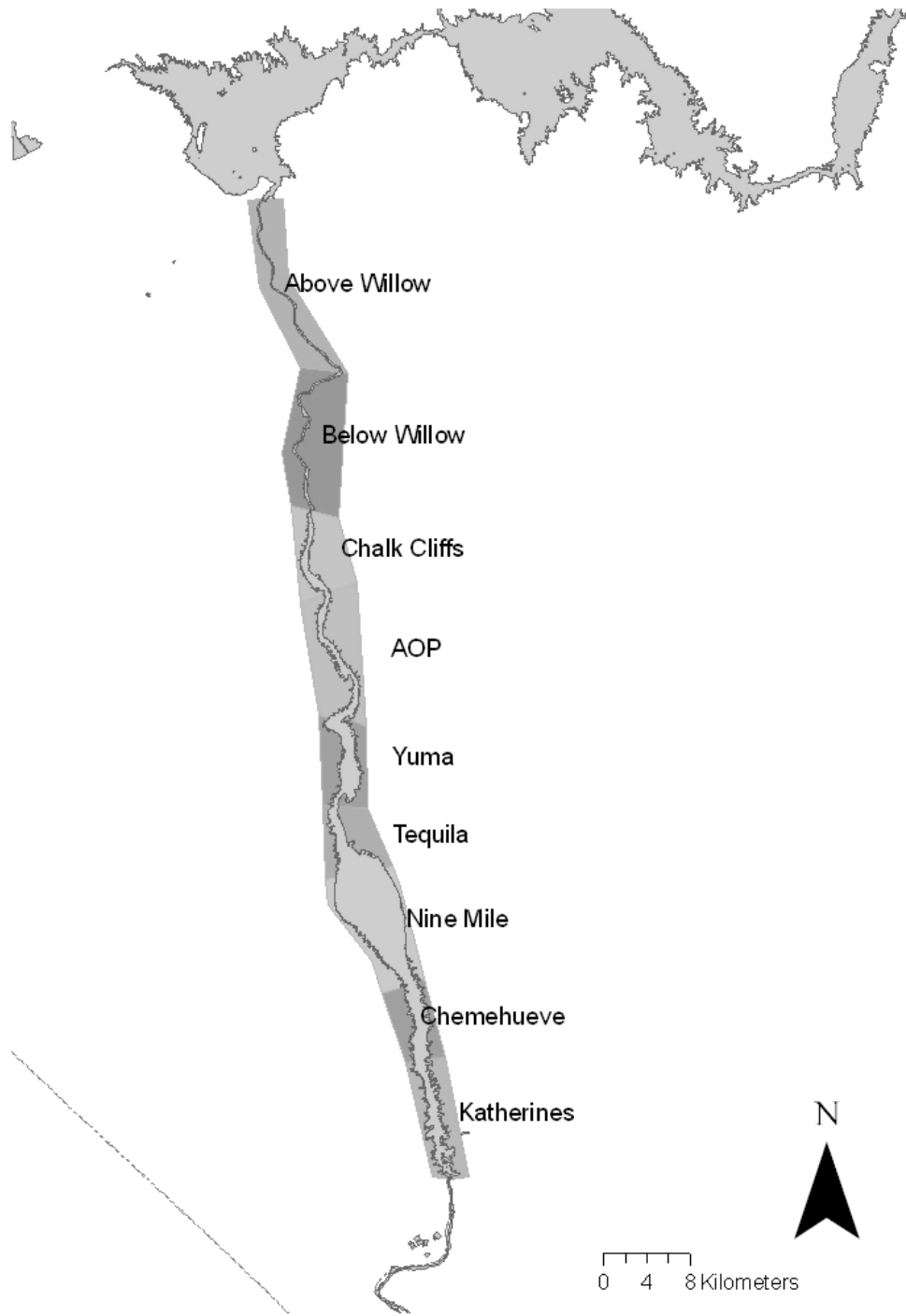


Figure 3. Specific zone names and boundaries used to analyze razorback sucker release, catch and effort data for Lake Mohave, Arizona and Nevada.

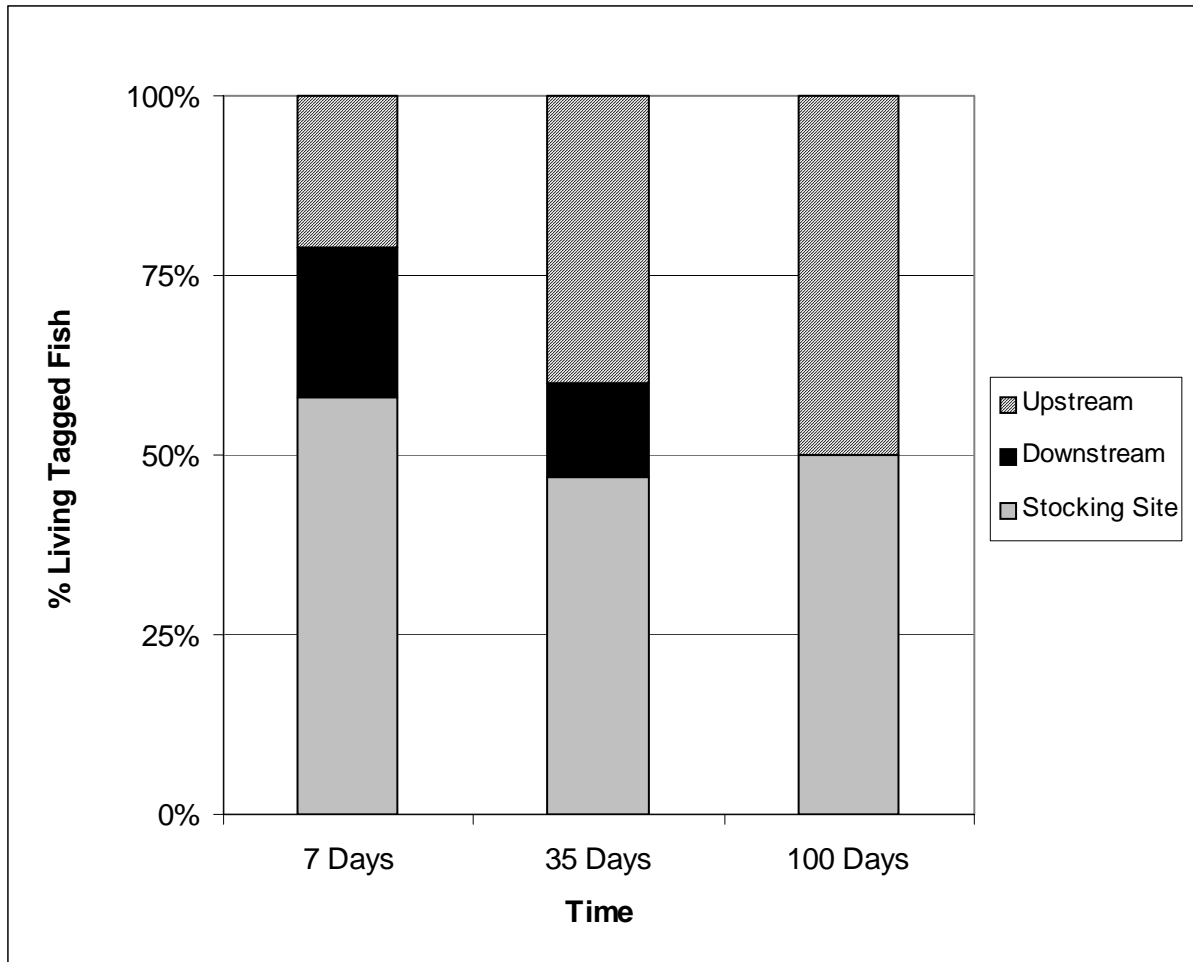


Figure 4. Movement patterns of tagged fish since their release in Fortune Cove, Lake Mohave, Arizona and Nevada. Sample sizes on Days 7, 35, and 100 reflect the total number of living fish that were still alive and actively being tracked.

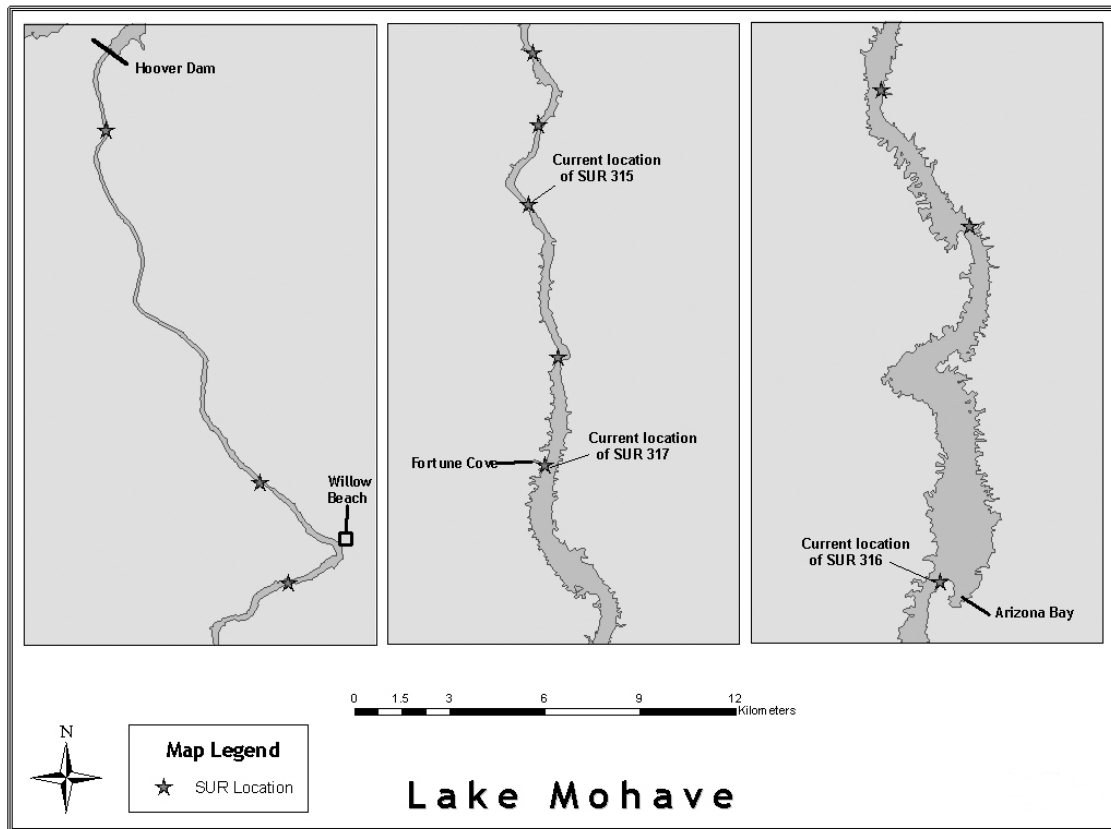


Figure 5. Locations of submersible ultrasonic receivers (SURs) between 27 September 2006 and 25 January 2007. Current SUR locations (as of 25 January 2007) are denoted on map.

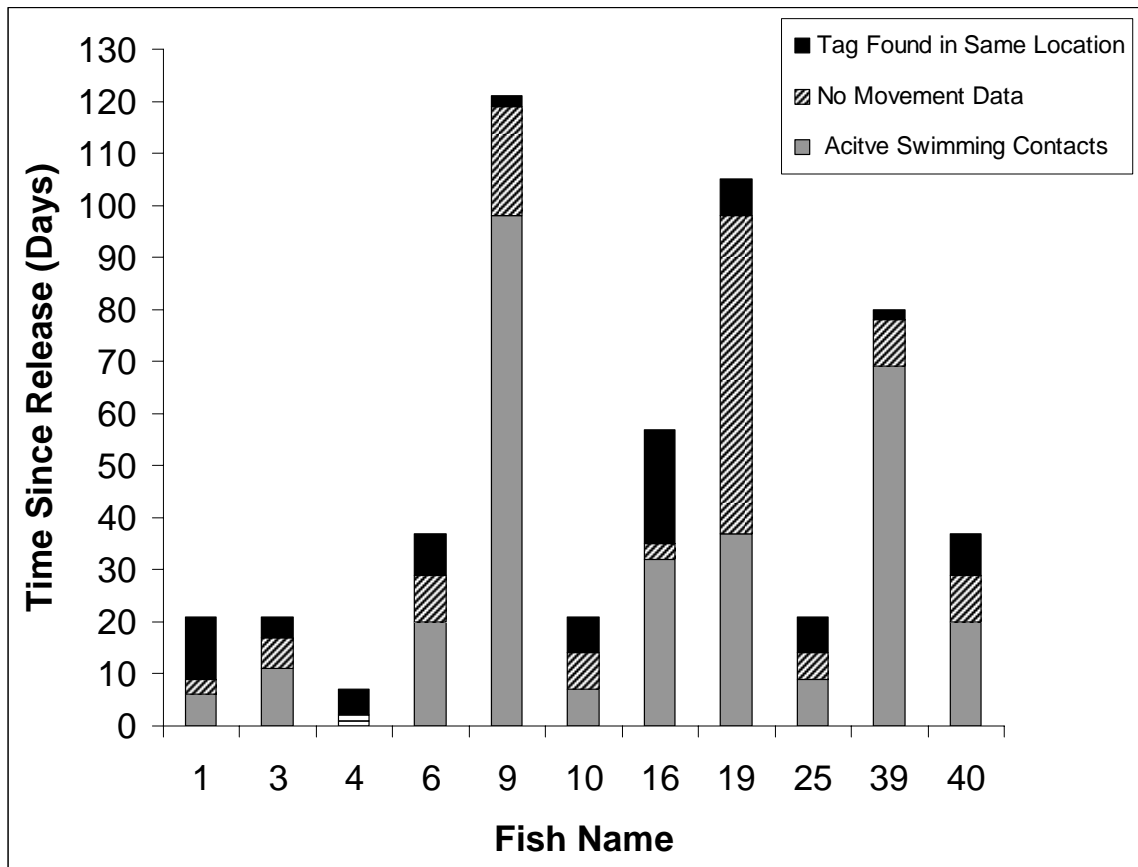


Figure 6. Swimming history of all eleven deceased, sonic tagged fish as of 25 January 2007, Lake Mohave, Arizona and Nevada.

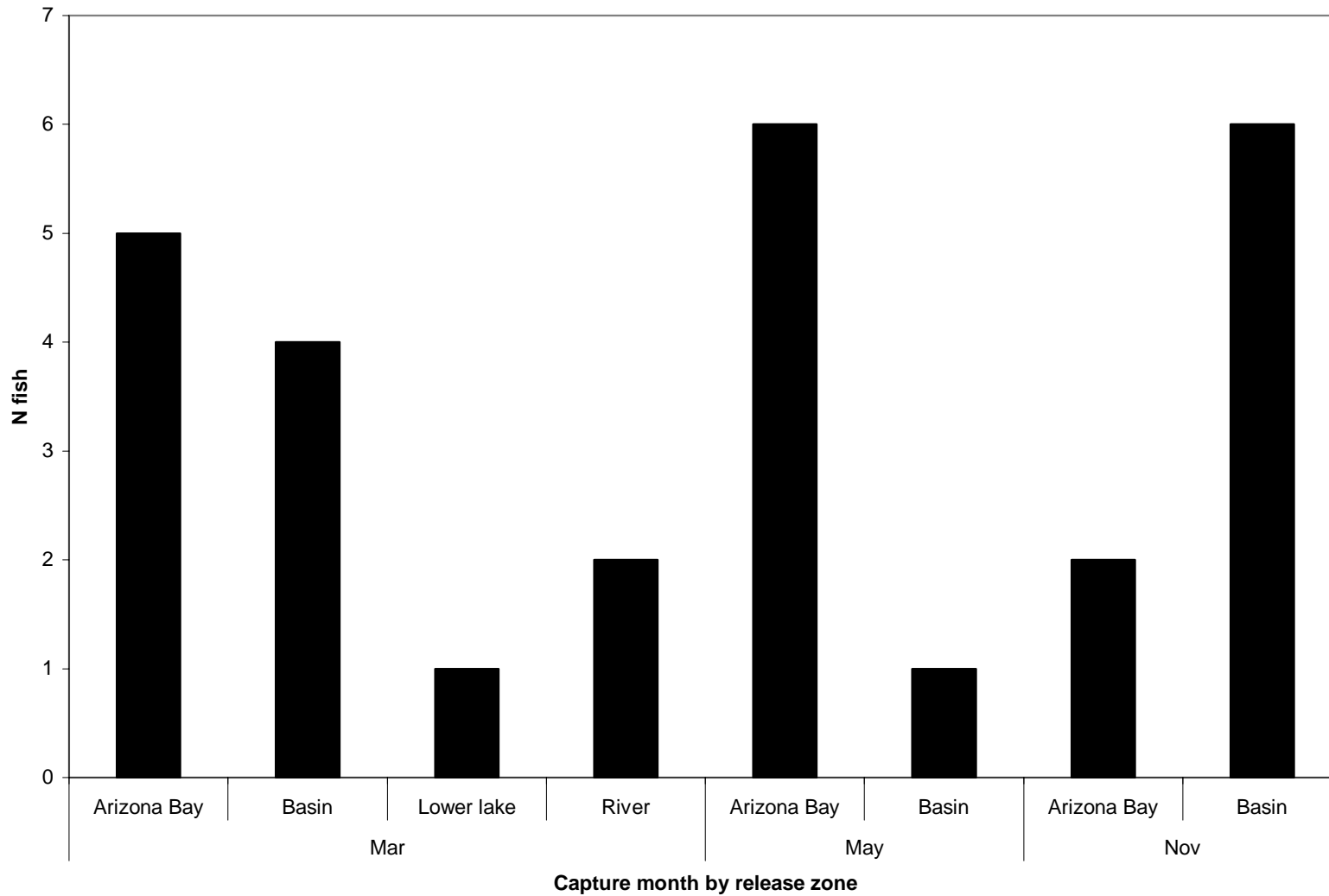


Figure 7. Release and capture zones from paired release-capture data of repatriated adult razorback sucker captured during March, May, and November 2006 monitoring events in Lake Mohave, Arizona and Nevada. All fish were captured in the Basin Zone.

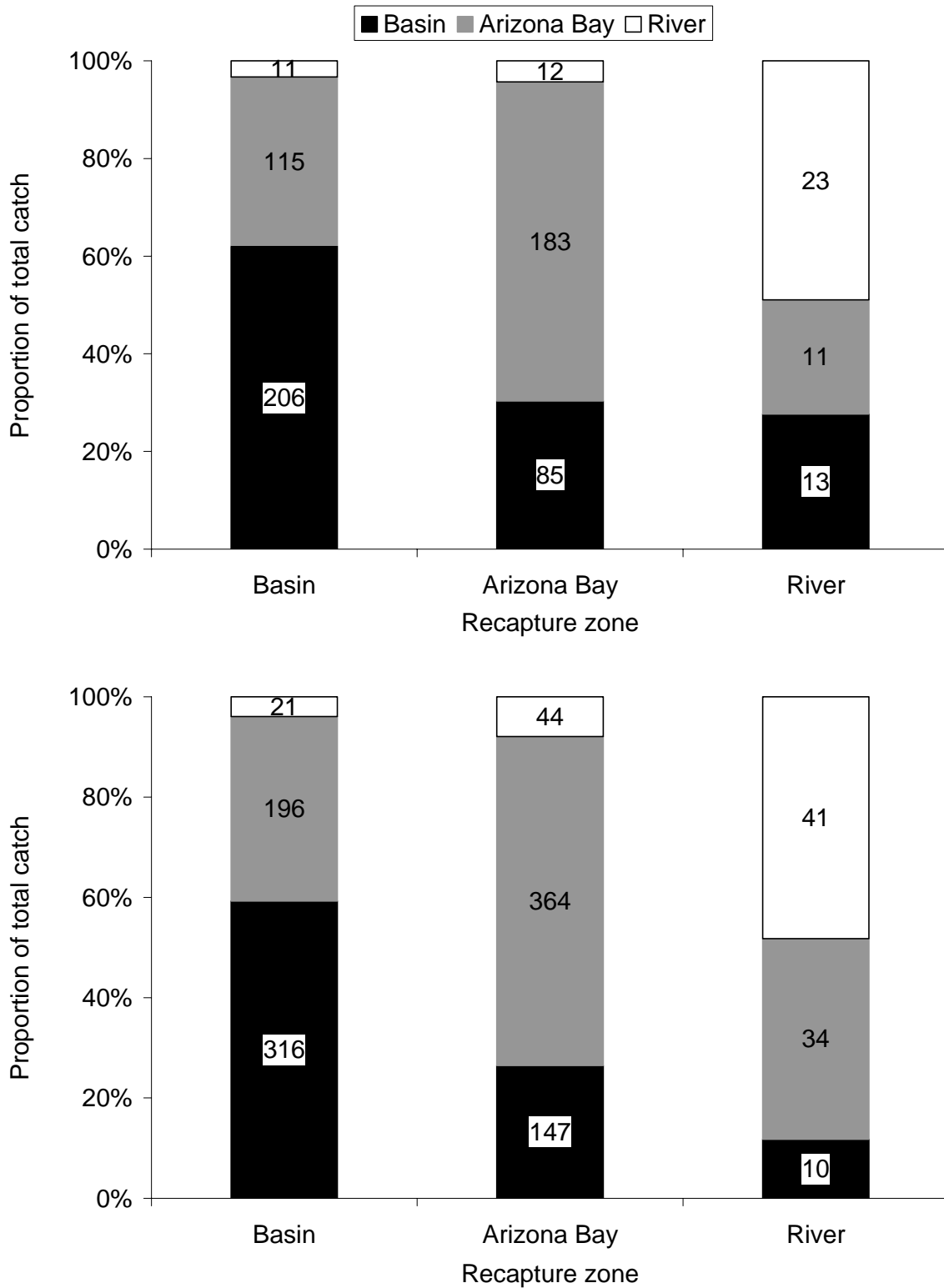


Figure 8. Proportion of wild razorback suckers captured in one of three lake zones; Basin (black), Arizona Bay (grey), and River (white), among three zones of recapture for fish at large between 180 and 440 days (top) and at large for more than 720 days (bottom), Lake Mohave, Arizona and Nevada. Capture and recapture data are from year-round sampling.

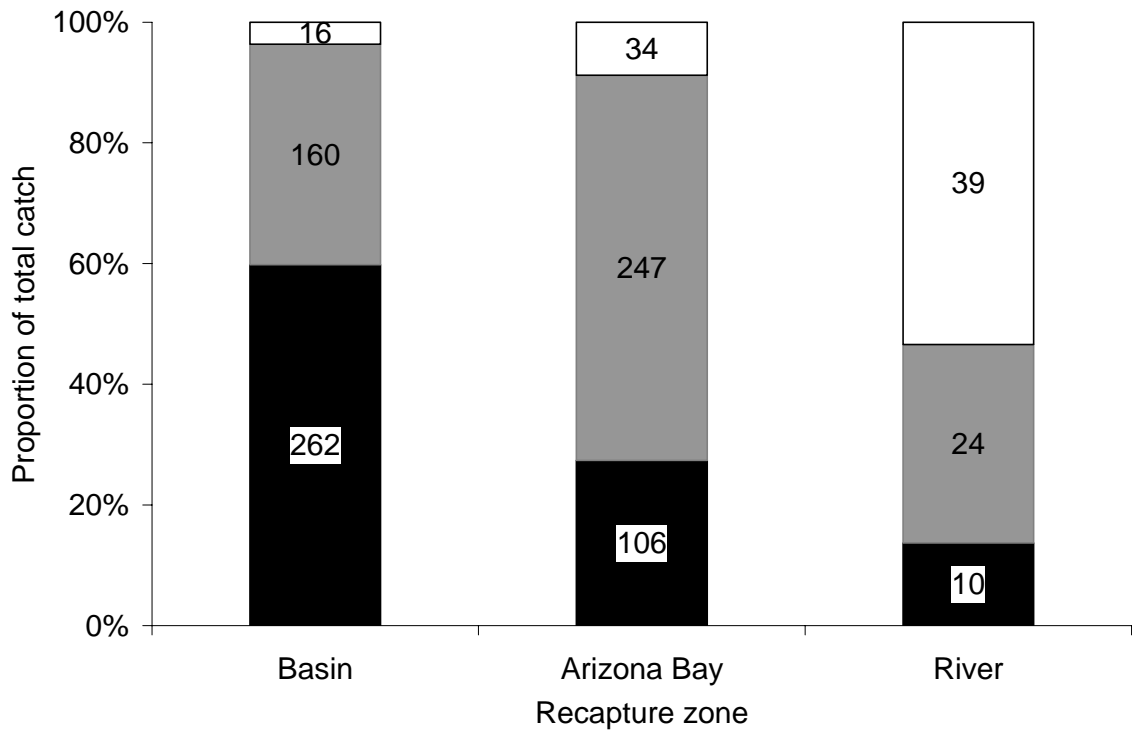
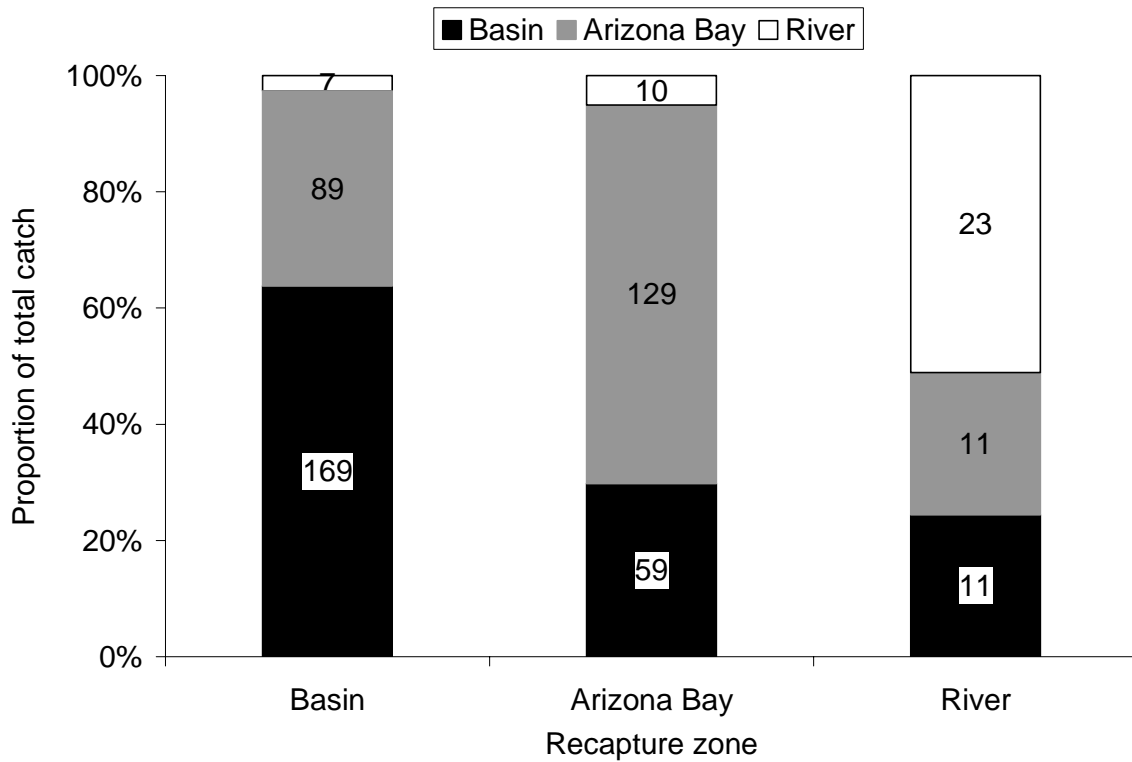


Figure 9. Proportion of wild razorback suckers captured in one of three lake zones; Basin (black), Arizona Bay (grey), and River (white), among three zones of recapture for fish at large between 180 and 440 days (top) and at large for more than 720 days (bottom), Lake Mohave, Arizona and Nevada. Capture and recapture data are from March (roundup) sampling.

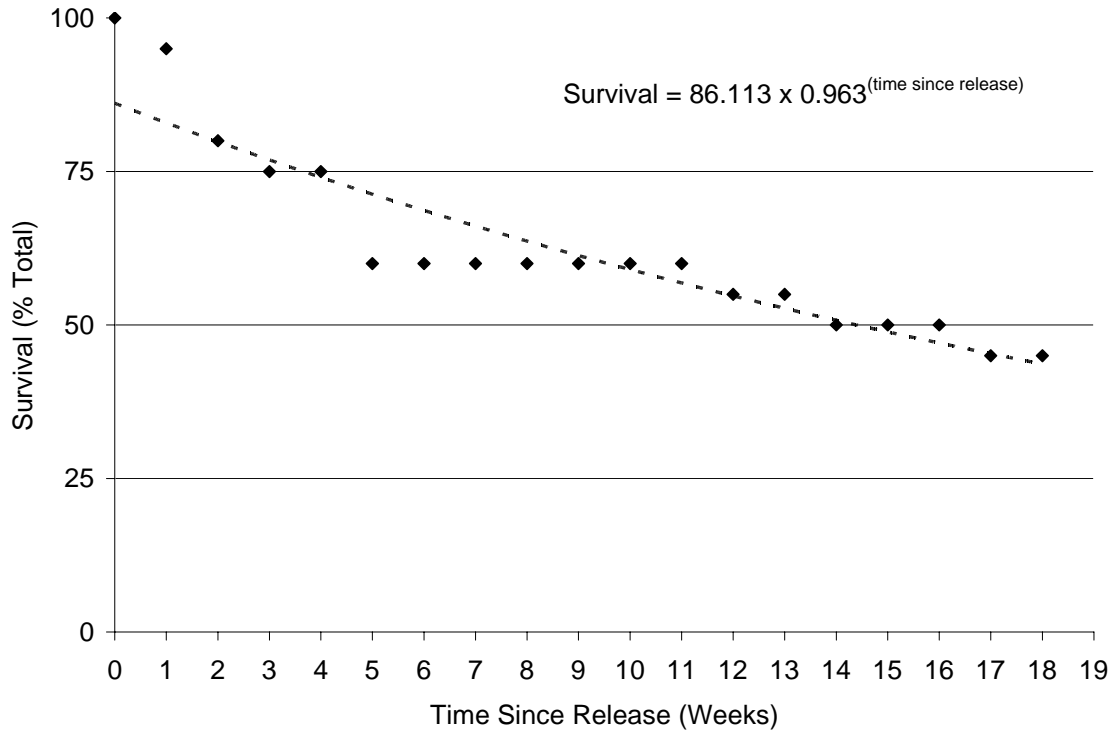


Figure 10. Weekly survival estimates for sonic tagged razorback suckers following their release from Fortune Cove, Lake Mohave, Arizona and Nevada, on 27 September 2006. Dashed line represents the predicted survival for tagged fish based on all data.

Table 1. Detailed swimming history of eleven tagged fish deceased as of 25 January 2007.

Fish 1
Fish 1 was initially contacted at the mouth of Fortune Cove (RM 41) approximately 30 minutes following its release. For the next ten hours it was repeatedly contacted in the main channel within 1.5 km of Fortune Cove. It was not contacted for two days, after which it was located near RM 36. The fish was presumed to be alive, because three days later it was contacted 2 km below this point. On 5 October, the fish was again contacted near RM 36 where it was repeatedly contacted in the same location until the 17 October 2006 when a SCUBA diver recovered the tag at a depth of 10 m. No fish remains were present.
Fish 3
Fish 3 was initially contacted at the mouth of Fortune Cove approximately 30 minutes following its release. The fish began a steady downstream journey, documented by both manual tracking and two SUR contacts. The first SUR contact occurred at night 7.5 km downstream of Fortune Cove. The fish was next contacted seven days later in weed laden, shallow water in the back of Roadrunner Cove. Two days later, the fish was contacted 2 km downstream of this point by an SUR at night. Six days after being contacted by the SUR, the fish was repeatedly contacted by manual tracking 0.5 km upstream of Roadrunner Cove. The tag was recovered from a depth of 13 m on 17 October 2006 near this site. No fish remains were present.
Fish 4
Fish 4 was initially contacted in the back of Fortune Cove three hours following its release. Later that evening, the fish was contacted in the main channel outside Fortune Cove. Over the next 24 hours, the fish began a steady upstream swim, as revealed by two separate SUR in two separate locations and once by manual tracking. One of these contacts occurred approximately 10.5 km upstream of Fortune Cove. Three days following its release from Fortune Cove, Fish 4 was repeatedly contacted near RM 45 (~ 9 km upstream of Fortune Cove). The tag was recovered from a depth of 6 m on 3 October 2006. No fish remains were present.
Fish 6
Fish 6 was initially contacted in the back of Fortune Cove nine hours following its release. It remained in Fortune Cove for the next 24 hours and was not contacted again for 19 days. Following this period of time, it was located in shallow water filled with submergent vegetation in the back of the first cove upstream from Fortune Cove (Elizabeth J. Cove). Water clarity was turbid due to flash floods on 13 October. Fish 6 was not contacted the next day and presumably had moved out of Elizabeth J. Cove. Nine days after this contact, Fish 6 was located 20.5 km downstream of Elizabeth J. Cove in the middle of the channel, at a depth of approximately 20 m. Six days later it was contacted in the same location and the tag was recovered on 2 November 2006. No fish remains were present.
Fish 9
Fish 9 was initially contacted in the back of Fortune Cove 25 minutes following its release. Thirty minutes later, it was contacted near the upstream shore at the mouth of Fortune Cove. Late that evening the fish was contacted by an SUR near Caulk Cliffs (RM 43) and subsequently found in the same vicinity by manual tracking the next day. Eight days later, Fish 9 was contacted at night by an SUR near Roaring Rapids (RM 49). The next day, the fish was located amidst submergent vegetation in shallow water approximately 1 km upstream from the previous contact. A considerable gap of time passed before locating Fish 9 again. On 2 January 2007, nearly 3 months later, Fish 9 was contacted among the steep cliff walls near Windy Canyon Light (RM 46). The fish was presumed to be moving since the next day it was not located. Three weeks later, Fish 9 was located near the downstream entrance to Windy Canyon (RM 45). It was contacted in the same location the next day. On 25 January 2007, a SCUBA diver recovered the tag at a depth of 8 m. No fish remains were present.

Table 1. Continued.

Fish 10
<p>Fish 10 was initially contacted in the back of Fortune Cove approximately 3 hours following its release. Six hours later, the fish was still located in the back of Fortune Cove. By the next day, Fish 10 had exited the stocking site and was located in the first cove upstream (Elizabeth J. Cove). Two days following its release, Fish 10 was located 3.5 km downstream of Fortune cove in the middle of the main channel near Liberty Cove. The next 3 contacts occurred in the main channel between this point and Fortune cove over the following 5 days. On 10 October, Fish 10 was located in the main channel, downstream of Liberty Cove near RM 38. Subsequent contacts were made in the same location over the next four days. Attempts to recover the tag on 17 October 2006 by a SCUBA diver were not successful. The sonic tag was likely covered by a fine layer of silt which had washed out of Liberty Cove following the flash flood hindering the diver's ability to see the tag. No fish remains were noted in the area where the signal strength was strongest at a depth of 10 m on the bottom of the river.</p>
Fish 16
<p>Fish 16 was initially contacted in the back of Fortune Cove approximately 9 hours following its release. Over the next two days the fish was twice located mid-channel approximately 1 km upstream of Fortune Cove. Five days later, Fish 16 was located in the first cove downstream of the stocking site (Oro Cove). On 16 and 17 October, the fish found its way back into Fortune Cove where the water was turbid due to flash floods that occurred on 13 October. Eight days later the fish was located in the main channel ~1km downstream of Chalk Cliffs. Over the next 4 days, Fish 16 was repeatedly contacted by an SUR placed at Fortune Cove. Three of these four SUR encounters took place during daylight hours. All four SUR contact periods were brief (1-9 minutes), indicating the fish was actively moving in the vicinity of the main channel. Three days later, Fish 16 was located in the main channel near Fellon Bend Cove (RM 44), approximately 10 km upstream from Fortune Cove. After contacting the fish in this same location for 3 days, a SCUBA diver was sent down to investigate. Due to poor visibility resulting from the 13 October flash floods, the tag could not be located. The next opportunity to re-deploy a diver did not occur for 20 days. On 22 November 2007, the tag was recovered from a depth of approximately 19 m. No fish remains were present.</p>
Fish 19
<p>Fish 19 was initially contacted at the mouth of Fortune Cove approximately 45 minutes following its release. Over the next 9 hours, the fish was contacted three times in the main channel near the mouth of Fortune Cove. Over the course of the next two days Fish 19 remained in the first cove downstream of the stocking site (Oro Cove). On 17 October, the fish was located in the main channel near Fortune Cove in turbid water due to the flash floods which occurred 4 days earlier. Between 26 October and 2 November, Fish 19 was contacted by the SUR located at Fortune Cove. All contacts were recorded at night. For two months, no contacts were made with Fish 19. Then, on 2 January 2007, the fish was located ~ 0.5 km upstream of Monkey Hole (RM 48). The fish was contacted in the same location two days later and on 10 January 2007, a SCUBA diver recovered the tag at a depth of 8 m. No fish remains were present.</p>
Fish 25
<p>Fish 25 was initially contacted in the Elizabeth J. Cove, the first cove upstream of Fortune Cove, approximately five hours following its release. That night, the fish was located in the back of Fortune Cove. Two days later, the fish was in the main channel near Liberty Cove (RM 38). On 1 and 2 October, the fish was located 4.5 km upstream of Fortune Cove near RM 44. Three days later it swam ~ 10 km downstream and was contacted in the main channel near RM 37. On 10 October it was located in the main channel near Red Cap Cove (RM 36). Two additional contacts were made in this location on two separate dates. On 17 October, a SCUBA diver recovered the tag from a depth of 9 m. No fish remains were present.</p>

Table 1. Concluded.

Fish 39

Fish 39 was not initially contacted until 29 days following its release at Fortune Cove. The first contact was detected by an SUR located at Painted Canyon Lights (RM 24). As luck would have it, the detection occurred only 2 hours prior to my arrival at Painted Canyon Lights. I was able to locate the moving fish several times over next 2 hours, located approximately 3.5 km downstream of this point, near Cottonwood Cove (RM 22). I assumed the fish was heading out to the open water of lake's basin. May be the fish's impression of the open waters of Lake Mohave were not what it expected because two days later, the fish was again detected by the SUR at Painted Canyon Lights. Forty eight hours later, the fish was contacted by the SUR at Fortune Cove. Two days after being detected at Fortune cove, Fish 39 was manually contacted near Burrow Wash (RM 49), ~5 km downstream of Willow Beach. The fish continued its upstream progression and was contacted 32 hours later by an SUR at the USGS Gauging Station (RM 54), ~3 km upstream of Willow Beach. In all, the fish swam upstream over 45 km in 133 hours. Based on the swimming behavior of the fish, it was presumed that Fish 39 was located somewhere between the uppermost SUR and Hoover Dam (RM 64). Despite intensive efforts the fish was not located again until 28 November and 4 December when the SUR at the USGS Gauging Station (RM 54) recorded its signal. The fish was still moving at this point in time. Nine days later, Fish 39 was contacted 1500 m upstream of Willow Beach. It was contacted in the same location over the next three days. Due to the exceedingly clear water conditions, I located the tag from the surface of the water. On 10 January 2007, a SCUBA diver retrieved the tag from a depth of 8 m. No fish remains were present.

Fish 40

Fish 40 was initially contacted at the back of Fortune Cove two days following its release. It was not contacted again for 18 days, at which time the fish was located near Chalk Cliffs (RM 43). Water clarity was poor due to the 13 October flash floods. Nine days later, Fish 40 was located 13 km downstream of Chalk Cliffs near Lookout Cove (RM 33). Subsequent contacts were made in the same location and on 2 November 2006, a SCUBA diver recovered the tag from a depth of 5 m. No fish remains were present.

Table 2. Razorback sucker monitoring summary in 2006 by month, tag, and history during March, May, and November monitoring events, Lake Mohave, Arizona and Nevada. Fish listed with “unknown” history are those fish without release information in the Native Fish Work Group database.

Capture month	Total N fish	Sex			PIT tag?		History		
		Female	Male	Juvenile/Unknown	Yes	No	Repatriate	Wild	Unknown
March	12	6	3	3	12	-	12	-	-
May	12	4	5	3	12	-	8	1	3
November	9	4	4	1	8	1 ^a		-	-
Total	33	14	12	7	32	1	29	1	3

One fish without tag was suspected to be a repatriated and its history was marked as such in the database.

a

Table 3. Time at large data from paired release-capture data of repatriated adult razorback sucker captured during March, May, and November monitoring events in Lake Mohave, Arizona and Nevada, in 2006. Release date is when fish, generally juveniles, were stocked into Lake Mohave.

PIT tag	Release date	Capture date	Days at large	Months at large	Years at large	Capture history
4637706D1F ^a	07-Feb-06	14-Mar-06	35	1	-	First capture in 2006
521F136644	16-Aug-00	15-Mar-06	2,037	68	6	First capture in 2001, second capture in 2006
7F7A082D4E	23-Jul-97	15-Mar-06	3,157	105	9	First capture in 2005, second capture in 2006
521C46752B	17-Aug-00	15-Mar-06	2,036	68	6	First capture in 2006
521C5F5610	14-May-02	15-Mar-06	1,401	47	4	First capture in 2006
4646597A50 ^b	31-Mar-05	15-Mar-06	349	12	1	First capture in 2006
4645734148 ^a	27-Jan-06	15-Mar-06	47	2	-	First capture in 2006
5330365743	20-Oct-05	16-Mar-06	147	5	-	First capture in 2006
46467B0F1D ^a	07-Feb-06	16-Mar-06	37	1	-	First capture in 2006
532107313A	23-Mar-01	17-Mar-06	1,820	61	5	First capture in 2006
4241357716	17-Jul-01	17-Mar-06	1,704	57	5	First capture in 2006
4647722A00 ^c	11-Jan-06	17-Mar-06	65	2	-	First capture in 2006
4637587C02 ^a	10-Jan-06	15-May-06	125	4	-	First capture in March 2006, second capture in May 2006
201D5F0E56	20-Nov-95	15-May-06	3,829	128	10	First capture in 2000, second capture in 2006
203857567B	20-Nov-95	15-May-06	3,829	128	10	First capture in 2001, second capture in 2006
7F7D183410	23-Nov-92	15-May-06	4,921	164	13	First capture in 2006
45737B633F ^b	29-Mar-05	15-May-06	412	14	1	First capture in 2006
46457E6104 ^b	31-Mar-05	15-May-06	410	14	1	First capture in 2006
46466E6E30 ^a	13-Jan-06	15-May-06	122	4	-	First capture in 2006
201D681447	20-Nov-95	12-Nov-06	4,010	134	11	First capture in 2002, second capture in 2006
257C60D875	02-Oct-06	12-Nov-06	41	1	-	First capture in 2006
257C60C3BB	02-Oct-06	13-Nov-06	42	1	-	First capture in 2006
257C62D817	04-Oct-06	13-Nov-06	40	1	-	First capture in 2006
257C629FOC	17-Oct-06	13-Nov-06	27	< 1	-	First capture in 2006
5215432479	10-Sep-98	15-Nov-06	2,988	100	8	First capture in 2000, second capture in 2006
424022714F	02-Oct-02	15-Nov-06	1,505	50	4	First capture in 2004, second capture in 2006
1F0E750B53	21-Sep-93	15-Nov-06	4,803	160	13	First capture in 2006

^a2003 year class, reared at Willow Beach NFH.

^b2001 or 2003 year class, reared at Willow Beach.

^c2002 year class, reared at Willow Beach NFH.

Table 4. Total length data from paired release-capture data of repatriated adult razorback sucker captured during March, May, and November monitoring events in Lake Mohave, Arizona and Nevada, in 2006.

PIT tag	TL (mm)					
	Release	Capture	Change in TL	Change in TL/day	Change in TL/month	Change in TL/year
4637706D1F	400	410	10	< 1	9	104
521F136644	390	605	215	< 1	3	39
7F7A082D4E	280	682	402	< 1	4	47
521C46752B	450	640	190	< 1	3	34
521C5F5610	330	643	313	< 1	7	81
4646597A50	355	460	105	< 1	9	110
4645734148	425	420	-5	< 1	-3	-39
5330365743	370	375	5	< 1	1	12
46467B0F1D	395	399	4	< 1	3	39
532107313A	440	647	207	< 1	3	41
4241357716	310	565	255	< 1	5	55
4647722A00	360	365	5	< 1	2	28
4637587C02	445	449	4	< 1	1	12
201D5F0E56	333	646	313	< 1	3	30
203857567B	346	672	326	< 1	3	31
7F7D183410	355	561	206	< 1	1	15
45737B633F	385	535	150	< 1	11	133
46457E6104	410	502	92	< 1	7	82
46466E6E30	385	412	27	< 1	7	81
201D681447	335	645	310	< 1	2	28
257C60D875	370	374	4	< 1	3	36
257C60C3BB	380	380	0	< 1	0	0
257C62D817	355	351	-4	< 1	-3	-37
257C629F0C	360	347	-13	< 1	-14	-176
5215432479	295	651	356	< 1	4	43
424022714F	340	550	210	< 1	4	51
1F0E750B53	238	612	374	< 1	2	28

Table 5. Rearing, release, and capture data from paired release-capture data of repatriated adult razorback sucker captured during March, May, and November monitoring events in Lake Mohave, Arizona and Nevada, in 2006.

Rearing type	Rearing location	Release site	Capture site	N fish	
Lakeside backwater	Arizona Juvenile	Arizona Juvenile	Carp Cove	1	
			Carp Cove (south of)	1	
	Dandy Cove	Dandy Cove	Carp Cove	1	
	Nevada Larvae	Nevada Larvae	Carp Cove	1	
	North Chemehuevi Cove	Chemehuevi Cove	Carp Cove (south of)	1	
	South Sidewinder Cove	Sidewinder Cove	Carp Cove	1	
	Yuma Cove	Yuma Cove	Carp Cove	1	
			Carp Cove (north point)	1	
			Carp Cove (south of)	1	
			Tequila Cove (north of)	2	
		Waterwheel and Carp Coves (between)	1		
Lakeside backwater total				12	
Off-site facility	Boulder City Wetlands Park	Cottonwood Cove	Carp Cove	3	
			Carp Cove (north point)	1	
		Nelson's Landing	Cottonwood Basin East	1	
	Bubbling Ponds NFH	Placer Cove	Carp Cove	1	
	Willow Beach NFH	Arizona Juvenile	Cottonwood Basin East	1	
			Gold Cove	Carp Cove	1
			Nevada Bay	Cottonwood Basin East	1
			Perkins Cove (south of)	Carp Cove	1
			Pot Cove	Carp Cove	1
			Red Tail Cove	Carp Cove	1
			Tequila Cove (north of)	1	
		Sheeptrail Cove	2		
Off-site facility total				15	
Grand Total				27	